

Remarks

Claims 1-20 are pending in the application. Through the amendments above and the arguments below that traverse the grounds for claims rejections, the patentability of the presently claimed invention is established.

I. Objections to the Drawings and Specification

The Office Action indicates that the drawings submitted on 27 February 2005 have been accepted but objected to by the Examiner based on incongruity between reference characters appearing the drawings, but not the specification, or vice-versa. The following corrections have been made to address items A) through F) of the instant Action:

A) Figure 3 and corresponding paragraph [0015] have been amended to clearly indicate component points A and B in the specification;

B) In response to the objection related to "components X, Y and Z", it is respectfully submitted that X, Y, and Z are not components of the radiofrequency coil, and that the Cartesian axes are only provided in Figures 4A and 4B to provide a 3D space frame of reference for the reader to better understand how the superposition of modes establishes a rotating magnetic field phasor B_{RF} 6 (shown in Figure 4C) orthogonal to the uniform static uniform field B_0 8 (shown in Figure 2) of the MR instrument. A sentence to this effect has been added to paragraph [0016]

C) Figure 3 has been amended to more clearly label tuning capacitors C_{MA} and C_{MB} 14, as well as fixed capacitor C_C 16, however L_{A-C} represent inherent inductances of the segments forming the base ring 12, rather than discrete, added components, so illustration as discrete components in a physical representation of the RF coil is not appropriate;

D) Paragraph [0018] has been amended to replace references to resistors R_{1-3} with R_{A-C} so as to agree with the reference characters appearing in Figure 6A;

E) As noted in D), paragraph [0018] has been amended to replace references to resistors R_{1-3} with R_{A-C} to agree with the description of Figure 6A. Paragraph [0018] has also been amended to make clearer that the components of the electronic equivalent circuit depicted are the representations of the same components described earlier in the specification; and

F) Paragraph [0018] has been amended to clarify that the reference characters in Figure 6B denote the same components of the RF coil described earlier in the specification.

In light of these amendments, Applicants respectfully request reconsideration and withdrawal of the objections to the drawings and specification.

II. Claim Rejections Based Upon Cited References

(a) Claims 1-19 were rejected under 35 U.S.C. §103(a) as unpatentable over Nabetani et al. (U.S. Pat. 6,348,794, hereinafter "Nabetani"), and claim 20 was rejected under 35 U.S.C. §103(a) over Natebani in further view of Lian et al. (U.S. Pat. 5,804,969.) Applicants respectfully traverse these rejections, in light of the remarks below distinguishing the presently claimed invention from the disclosure of the cited references.

(b) With respect to claim 1, the instant Action asserts that Natebani discloses the limitations of the claim, except that it lacks disclosure of the exact terminology of *annular base ring conductor* and *arcuate* shapes when referring to the coil pieces, but that it would have been obvious to one of ordinary skill in the art at the time the invention was made that Natebani's "rectangular base in a ring/loop formation" (connection lines 10-13) meet the *annular base ring conductor* terminology and that the coils 1-3 meet the *at least one arcuate conductor* terminology.

Nabetani discloses an RF coil system comprised of coil arrays made up of three or more individual coil pieces, each loop aligned parallel to one another. These coil pieces constitute the arcing loop pieces 1, 2, and 3 to which the ends of the parallel connection lines 10-13 connect (Figures 1, 2 and 5.) Their geometries, orientation with respect to connection lines 10-13, connections to connection lines 10-13 all differ from the limitations of claim 1, as does the geometry and purpose of connection lines 10-13 themselves.

Firstly, Nabetani describes the purpose of the parallel connection lines 10-13 as purely for connecting the three or more pieces of coils that make up the arcing loop pieces. As such, they serve no purpose in the reception of the MRI signal. Moreover, the disposition of the parallel connection lines 10-13, as shown in Figures 1, 2, 3 and 4, is clearly neither *annular* nor in a *ring having a central axis*. The parallel connection lines 10-13 clearly define a rectangular base in a loop formation, and cannot be construed as annular base ring conductor. While the specification defines the term *arcuate* to include non-hemispherical geometries, the term *annular*

is well understood to have a plain meaning of a circular or elliptic arrangement, not a rectangular loop as interpreted in the instant Action.

Secondly, Nabetani explicitly specifies a plurality of capacitors disposed between segments in each of the parallel connection lines 10-13. These capacitors alter the electrical coupling of the coils 1-3 [Figures 2, 3 and 4] in the sense of affecting self and mutual inductances between the coils. Claim 1 recites, in part, a connection of the *arcuate conductor...having two ends, one end terminating in direct contact with the base ring conductor, the other end electrically connected to the base ring conductor via at least two of the plurality of capacitive electrical connections...* (emphasis added.) Even if any of coils 1-3 were interpreted as the equivalent of an *arcuate conductor*, it is clear that that every connection of each of the coils 1-3 is a direct connection to the rectangular loops formed by connectors 10-13 (as noted in paragraph 8 of the Action) and none of the connections of the coils 1-3 to the connectors 10-13 is *through a capacitive electrical connection*. The Action does not explain how Natebani discloses this latter limitation, and only refers generally to practically the entirety of the specification, "col. 1 line 27 through col. 8 line 57."

Thirdly, none of the coils 1-3, interpreted for the sake of this point as *arcuate conductors*, are *symmetrically disposed with respect to the central axis of the base ring conductor*. The Action asserts that coils 1-3 are symmetrically disposed with respect to the rectangular loops formed by connectors 10-13, but does not provide support for this assertion. In actuality, connectors 10-13 form two rectangular loops. Applicants respectfully assert that there is no central axis that can be drawn for these loops about which any of coils 1-3 is symmetric.

In summary, the Natebani's coil geometry cannot be modified so as to derive the coil structure as recited in claim 1. Nor can Natebani's coil configuration operate as can the coil recited in claim 1, i.e., Natebani's coil cannot be positioned so as to encircle a female breast. In light of Natebani's failure to teach or suggest the limitations as recited in claim 1, Applicants respectfully submit that claim 1 is patentable over the cited art. Similarly, dependent claims 2-19 are patentable over the cited art. If an independent claim is nonobvious, claims that depend from the independent claim are also nonobvious. *In re Fine*, 837 F.2d 1071, 1071; 5 USPQ2d 1596 (Fed. Cir. 1988). Reconsideration and withdrawal of this ground for rejection is, thus, respectfully requested.

(c) Further comments with regard to the rejections of dependent claims 2-19 are provided now.

With respect to claim 2, Applicants respectfully submit that the assertions of claim 10 that Natebani disclose a *single arcuate conductor, phase quadrature* embodiment represents a misreading of Natebani. As previously described, the parallel connection lines 10-13 do not constitute any part of the active MRI coil system. They only serve the purpose to electrically decouple the arcing loops 1-3 that make up the coil system, thus making phase quadrature operation impossible for the design. The effects of the magnetic field produced in the parallel connection lines 10-13 on the coil system as a whole are not considered. Also, and most importantly, the parallel connection lines 10-13 do not have any ports where the MR signals can be obtained. The system can only receive the MR signal at points 7, 8 and 9 (see Figure 1), where cables 21, 22 and 23 are located. As such, phase quadrature operation would produce no improvements in the received or transmitted signals.

With respect to claims 3 and 4, the instant Action again refers to almost the entirety of Natebani's specification, rather than specifically identifying where Natebani discloses that connectors 10-13 are *capable of establishing a first of the two modes as a result of current flowing circularly through the annular base ring conductor*, or that *a second of the two modes is established by 90° phase shifted current flowing through the arcuate conductor and split between two halves of the annular base ring conductor*. Due to the locations Natebani's receiving ports 7-9 of the MR signals, it is impossible to establish a second mode of operation by splitting the 90 degree phase shifted current flowing through the arcuate conductors into two halves in the parallel connection lines 10-13. Only one mode is possible, which is shown in Natebani's Figures 2 and 3. Furthermore, the current flow in the parallel conduction lines 10-13 always describes a complete loop, in direct contrast to the recited limitation wherein current flows circularly (in a first mode) and 90-degree phase shifted (second mode) through, respectively, the annular base ring as well as the arcuate conductor and the two halves of the annular base ring.

With regard to claim 5, Figure 5 in Nabetani depicts the deployment of a coil arrangement in an MRI apparatus (300) whose main magnetic field (B0-field) is orientated vertically with respect to the axis of the coil arrangement. As a result, Natebani's coil

arrangement receives its MR signal as a result of the coil arrangement being perpendicular to the main magnetic field (B₀-field). Such a deployment is contrary to the use of the coil arrangement recited in the claims, wherein the main field (B₀-field) is aligned horizontally to obtain an MRI signal response, as seen in Figure 2.

With regard to claims 6 and 7, the instant Action asserts that Natebani discloses that the *base ring conductor is comprised of microstrip line segments* and that the *arcuate conductor* can be similarly composed. Nabetani does not address the use of microstrip lines for either the parallel connector lines 10-13 or coils 1-3. As noted above (see response to the rejections of claims 1 and 2), the parallel connection lines 10-13 provide electric decoupling of arcing coils 1-3 with the assistance of intermediary connecting capacitors 4-6 and neutralizing capacitors 14-17. For that purpose, transmission line properties are unimportant and are not accounted for in Natebani's Equations 1-24. However, the electrical properties of a microstrip line cannot be neglected when used to form a *base ring conductor* as recited in Applicants' claims, because microstrip lines possess appreciable inductance and resistance, which would invalidate Natebani's Equations 1-24. Thus, Nabetani cannot use microstrip lines in the construction of the parallel construction lines 10-13 and retain the validity of Equations 1-24.

With regard to claims 8 and 9, although Nabentani discusses the use of neutralizing capacitors in the arcing loops 1-3 to establish resonance, these capacitors are shown as fixed-valued and not tunable, as seen in Figures 2, 3 and 4.

With regard to claim 10, Nabentani teaches the compensation of the mutual inductance between arcing loops 1-3 as described by Equations 8, 9, 10 and 18-24. In contrast, the presently claimed invention compensates the total reactance in order to tune and match the coil configuration to the target resonance frequency. It is noted that I₁, I₂ and I₃ [in Figures 2 and 3] refer to the current in the arcing loops 1-3 with resistances R₁, R₂ and R₃, and do not constitute reactances as asserted by the Action.

With regard to the rejection of claim 12, the terminology *dimensioned so as to receive a human breast* implies that the radio frequency coil geometry is explicitly designed to only cover the volume around the female breast. The verb "receive" in the context of the application implies that the female breast resides within the anatomically shaped coil. In contrast, the coil described by Nabentani cannot uniquely target an anatomical region such as the breast.

With regard to the rejection of claim 13, although Nabetani shows at least two electrical ports, there is no disclosure as to how the ports would interface with a single or multi-channel receiver. Interfacing with a single-channel would require non-trivial additional electric circuitry to combine all three signals from ports 7, 8 and 9. This additional circuitry is neither shown nor discussed.

With regard to the rejection of claims 14 and 15, Nabentani discloses only a single coil assembly consisting of three or more non-overlapping coils specifically designed for a vertical MRI system [as seen in Figure 5], whereas the presently claimed invention envisions an embodiment with two distinctly different separate coil arrangements, each comprised of annular base rings and single or multiple arcuate loops. The microstrip arrangements are specifically designed and shaped in order to adhere to the anatomical shape of the female breast.

With respect to the rejection of claim 17, Nabetani discloses an RF coil system for MRI imaging having three or more non-overlapping coil loops that are electrically isolated from each other. In such a design, the received MR signals at points 7, 8 and 9 are processed in parallel and independent of one another. Consequently, no electric circuit is disclosed that teaches how to interface the individual ports with a single-channel receiver.

With respect to the rejection of claim 19, Nabetani discloses use of a pair of back-to-back diodes [Figure 4]. During receive mode of operation, the MR signal generates a low voltage that is below the diodes' threshold voltage and therefore the diodes are "turned off". During transmit mode of operation, the large induced voltage exceeds the diodes' threshold voltage and therefore the diodes are "turned on". As recited in claim 19, the deployed PIN diodes have very different electrical properties and are in no way similar to a pair of back-to-back diodes. For the PIN diode to switch between high and low impedance states, an external DC bias voltage is supplied.

(d) Claim 20 was rejected under 35 U.S.C. §103(a) as unpatentable over Nabetani in further view of Lian. Applicants respectfully traverse this rejection, in light of the remarks below distinguishing the presently claimed invention from the disclosure of the cited references.

Lian fails to provide the disclosure missing from Nabetani of the limitations as recited in claim and as described in detail above. In addition, Nabentani describes a coil system specifically

designed for a vertical MRI system [see the MR apparatus shown in Figure 5], whereas the present invention comprises a radio frequency coil system that operates in a horizontal MRI system (see for instance Figure 2 in the instant application.) The type of MRI system critically determines the spatial orientation of the radio frequency coils (since the field of the radio frequency coil must be perpendicular to the main magnetic field or B₀-field).


In Lian, the circuitry defined as component 14 [see Figure 1] is not part of the RF coil system, and hence cannot be considered as an annular base ring conductor. Circuitry 14 establishes the interface between the dual loop configuration, 12a and 12b, and the transmitter (Tx) and receiver (Rx) switch 26. The independent loops 12a, 18a, 12b, 18b do not teach orthogonal and coupled loop orientations, as proposed between the base ring and the arcuate conductor/conductors in this patent application.

(e) In light of at least the foregoing, Applicants respectfully submit that neither Natebani alone, nor in combination with Lian, teach or suggest the apparatus recited in claims 1-20, and therefore request reconsideration and withdrawal of both the rejections of said claims. Claims 1-20 are now in a condition for allowance, and a notice to that effect is earnestly solicited. If any questions arise during the review of this amendment/reply, the Examiner is invited to contact the undersigned at (617) 854-4000 to discuss any issue.

Respectfully submitted,

REINHOLD LUDWIG, et al.,
Applicants

Date: December 9, 2005

By: 
John A. Hamilton,
Reg. No. 48,946
Attorney for Applicants